NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2632

CORROSION OF MAGNESIUM ALLOY ZK60A IN MARINE ATMOSPHERE AND TIDEWATER

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SUMMARY

The corrosion resistance of unprotected magnesium-zinc-zirconium alloy ZK60A was determined in a marine atmosphere and in tidewater. The unprotected alloy was so rapidly attacked in tidewater that it would be of no practical value in applications subject to wetting by sea water. In the marine atmosphere the rate of corrosion was much less and the alloy should give good service if adequately protected.

INTRODUCTION

This report summarizes the results of an investigation of the resistance of magnesium alloy ZK60A to corrosion in a marine atmosphere and in tidewater. It is one of a series of reports covering the investigation of the corrosion characteristics of aircraft alloys conducted under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics, the Bureau of Aeronautics, Department of the Navy, and the Wright Air Development Center, U. S. Air Force.

MATERIALS AND PROCEDURE

The material investigated was magnesium-zinc-zirconium alloy ZK60A supplied as an extrusion 1/16 inch thick by 1 inch wide which had received no surface protective treatment. Magnesium alloy AZ31A-H, exposed at the same time, was used to compare the corrosion characteristics of the materials. This latter material was in sheet form 0.064 inch thick and was received in the "oiled" condition with no other surface treatment.

The chemical compositions of the materials are given in table 1. The composition of the ZK60A was determined by chemical and spectrochemical analyses at the National Bureau of Standards, while that of the AZ31A-H material is the type composition.

The ZK60A extrusion was cut into 14-inch lengths and the AZ31A-H sheet into 4- by 14-inch panels, then degreased in carbon tetrachloride and alcohol. The bare cleaned panels and strips were exposed in the tidewater and in the marine atmosphere at the Naval Air Station, Norfolk, Virginia.

RESULTS AND DISCUSSION

After 6 months of exposure in the tidewater the surfaces of the ZK60A alloy were deeply pitted as shown in figure 1. These surfaces were so irregular and uneven that it was impossible to measure the depths of the pits on the transverse sections by the usual technique. Therefore, to determine the extent of attack it was necessary to measure the thicknesses of sound metal remaining between the bottoms of pits on opposite sides of the specimens. Average values of these measurements are given in table 2. Similar values for AZ31A-H are included to give a comparison of the behavior of the two materials.

A typical example of the pitting of the ZK60A specimens and the minimum thickness of metal remaining after exposure in the tidewater is shown in figure 2.

It is difficult to make direct comparisons in depths of pits because of the extremely deep pitting and roughened surface of the ZK60A alloy. However, it is apparent from the values in table 2 and from figure 2 that the attack on this alloy was very rapid and severe, considerably more so than that on the AZ31A-H alloy.

In the marine atmosphere both alloys turned dark gray in color and later became speckled with light-gray corrosion products. The products on the ZK60A specimens after 6 months' exposure are shown in figure 1. The depths and widths of the corrosion pits on polished transverse sections of both alloys after exposure to the marine atmosphere are given in table 3.

These results indicate that after 6 months of exposure the corrosion pits in the ZK60A alloy were deeper and wider than those in the AZ31A-H alloy. Typical corrosion pits in the ZK60A alloy after 6 months of exposure are shown in figure 3. An idea of the difference in the rapidity of attack between exposure in tidewater and in marine atmosphere can be obtained by comparing the thickness of the remaining metal in figure 2 with that in figure 3.

During the next 12 months of exposure, the rate of penetration of the ZK60A alloy decreased but the width of pits increased indicating that the localized attack was becoming less and the general attack was more prevalent. Typical pits in this alloy after 18 months of exposure are shown in figure 4. No comparison could be made with the AZ31A-H alloy because no specimens of the latter alloy were removed at that time.

The results of tensile tests made on the alloys before and after exposure are given in table 4.

The results of the tensile tests of the unprotected ZK60A alloy after exposure in the tidewater reflect its great susceptibility to corrosion in this medium. The yield strength could not be determined because the specimens broke through deep pits before the yield point could be reached; the tensile strength was reduced by more than half and the elongation to less than 1 percent. Under the same conditions of exposure the yield and tensile strengths of the unprotected AZ31A-H alloy were about 75 percent of those of the unexposed material and the elongation was about 4 percent. This indicates very clearly that the ZK60A alloy should not be used in the unprotected condition where it would be subjected to wetting by sea water. However, after 6 months of exposure in the marine atmosphere, the tensile properties of neither alloy were greatly affected. There was a slight decrease in the yield strength and elongation of the ZK60A alloy after 6 months of exposure while there was practically no change in the AZ31A-H alloy.

After 18 months of exposure in the marine atmosphere the ductility of the ZK60A alloy was definitely impaired, the elongation decreasing from 13 to 5.5 percent. There were slight decreases in the tensile and yield strengths.

The corrosion resistance of the unprotected ZK60A alloy was not so good as that of the unprotected AZ31A-H alloy in either environment. To obtain an adequate service life for any application involving the use of ZK60A in the marine atmosphere for any extended period of time the structure should be well-protected by the application of a good chemical surface treatment and a good paint system.

CONCLUSIONS

From an investigation of the corrosion resistance of unprotected magnesium-zinc-zirconium alloy ZK60A in a marine atmosphere and tidewater it was found that:

1. The corrosion resistance of unprotected magnesium-zinc-zirconium alloy ZK60A was inferior to that of unprotected AZ31A-H alloy in both a marine atmosphere and tidewater.

2. The corrosion rate of the unprotected ZK60A alloy was very great in tidewater, precluding its use for any application in which it would be subject to wetting by sea water.

3. Unprotected ZK60A should be used in the marine atmosphere only in applications where its life expectancy is relatively short, possibly 3 to 5 years. However, its life expectancy would be increased considerably if the alloy is protected by the application of a good chemical surface treatment and a good paint system.

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TABLE 1

CHEMICAL COMPOSITIONS OF MAGNESIUM ALLOYS

Element	Composition (percent by weight)	
	ZK60A	AZ31A-H
Aluminum	-----	2.5-3.5
Manganese	0.07	[a].20
Zinc	5.7	.7-1.3
Zirconium	.6	-------
Silicon	-----	[b].3
Copper	-----	[b].05
Nickel	-----	[b].005
Iron	.001	[b].005
Other impurities	-----	[b].3

[a]Minimum content.

[b]Maximum content.

TABLE 2

THICKNESS OF ZK60A AND DIMENSIONS OF PITS IN AZ31A-H

AFTER 6 MONTHS OF EXPOSURE IN TIDEWATER

ZK60A	
Average original thickness of metal, in.	0.060
Average thickness of metal after exposure, in. . .	.032
Minimum thickness of metal after exposure, in. . .	.010
AZ31A-H	
Average original thickness of metal, in.	0.064
Average depth of corrosion pits, in.	.002
Deepest pit, in.	.020
Average width of corrosion pits, in.	.006
Widest pit, in.	.035

TABLE 3

DEPTHS AND WIDTHS OF CORROSION PITS AFTER EXPOSURE

IN MARINE ATMOSPHERE

Material	Exposure period (months)	Average depth (in.)	Deepest pit (in.)	Average width (in.)	Widest pit (in.)
AZ31A-H	6	0.0005	0.0015	0.0041	0.034
ZK60A	6	.0026	.004	.0072	.0125
ZK60A	18	.0035	.008	.0181	.0375

TABLE 4

TENSILE PROPERTIES OF MAGNESIUM ALLOYS ZK60A AND AZ31A-H

BOTH UNEXPOSED AND EXPOSED

Material	Exposure period (months)	Environment	Tensile strength (psi)	Yield strength, 0.2-percent offset (psi)	Elongation (percent in 2 in.)
ZK60A	0	Unexposed	50,000	39,500	13.0
AZ31A-H	0	------do------	41,300	33,100	12.7
ZK60A	6	Tidewater	22,500	(1)	.7
AZ31A-H	6	------do------	33,200	24,200	4.1
ZK60A	6	Marine atmosphere	49,700	37,200	10.9
AZ31A-H	6	------do------	41,900	32,500	12.7
ZK60A	18	------do------	45,200	37,800	5.5

[1]Specimens broke through deep pits before yield point was reached.

Figure 1.- Appearance of ZK60A specimens after 6 months of exposure in tidewater (top four) and in marine atmosphere (bottom two, earthward surfaces). X5/8.

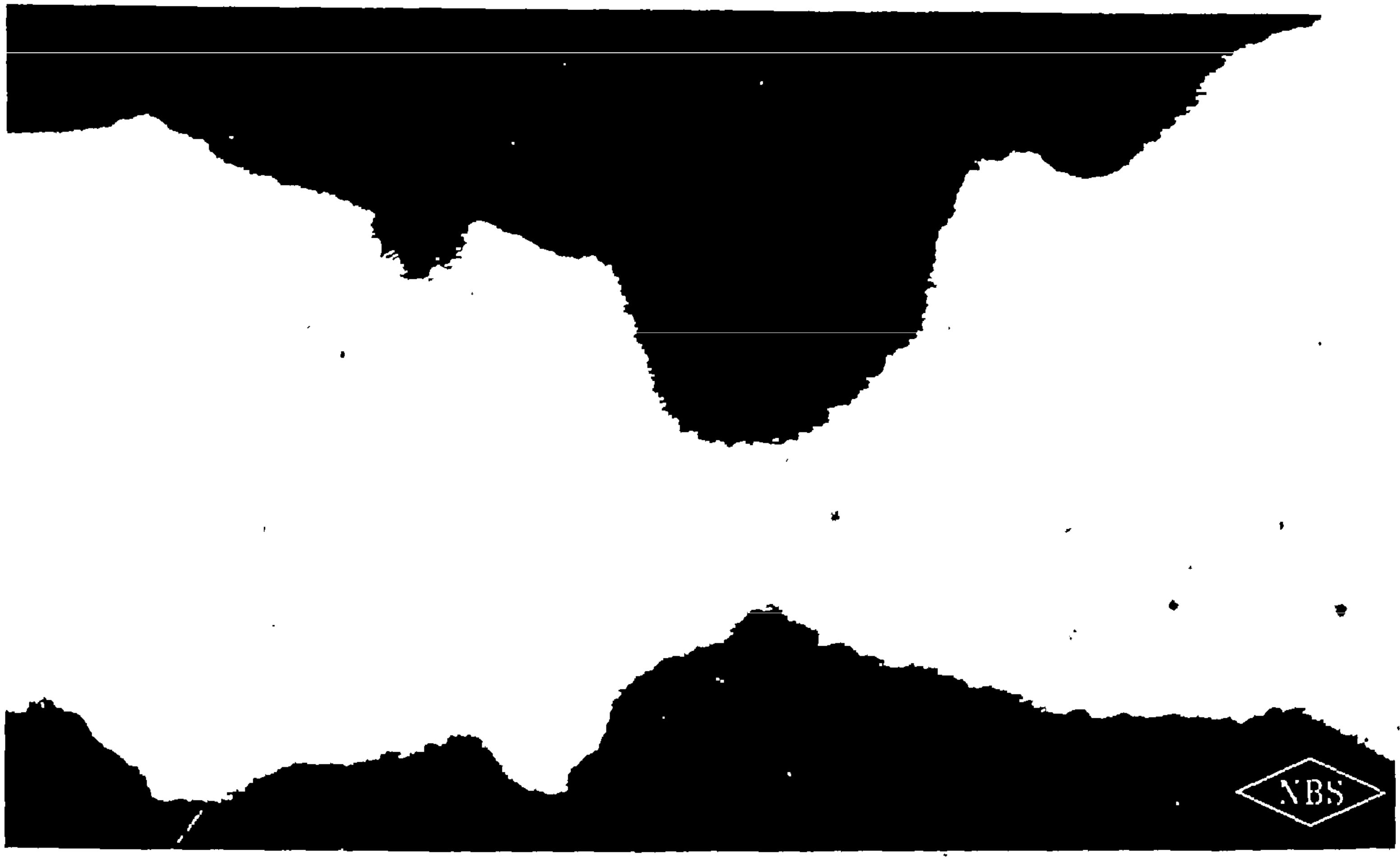

Figure 2.- Cross section of specimen of ZK60A alloy showing type of pitting and minimum thickness of remaining metal after exposure in tidewater for 6 months. X100.

Figure 3.- Typical pits in ZK60A material after 6 months of exposure in marine atmosphere. Compare thickness of this sheet with that of one in figure 2. X100.

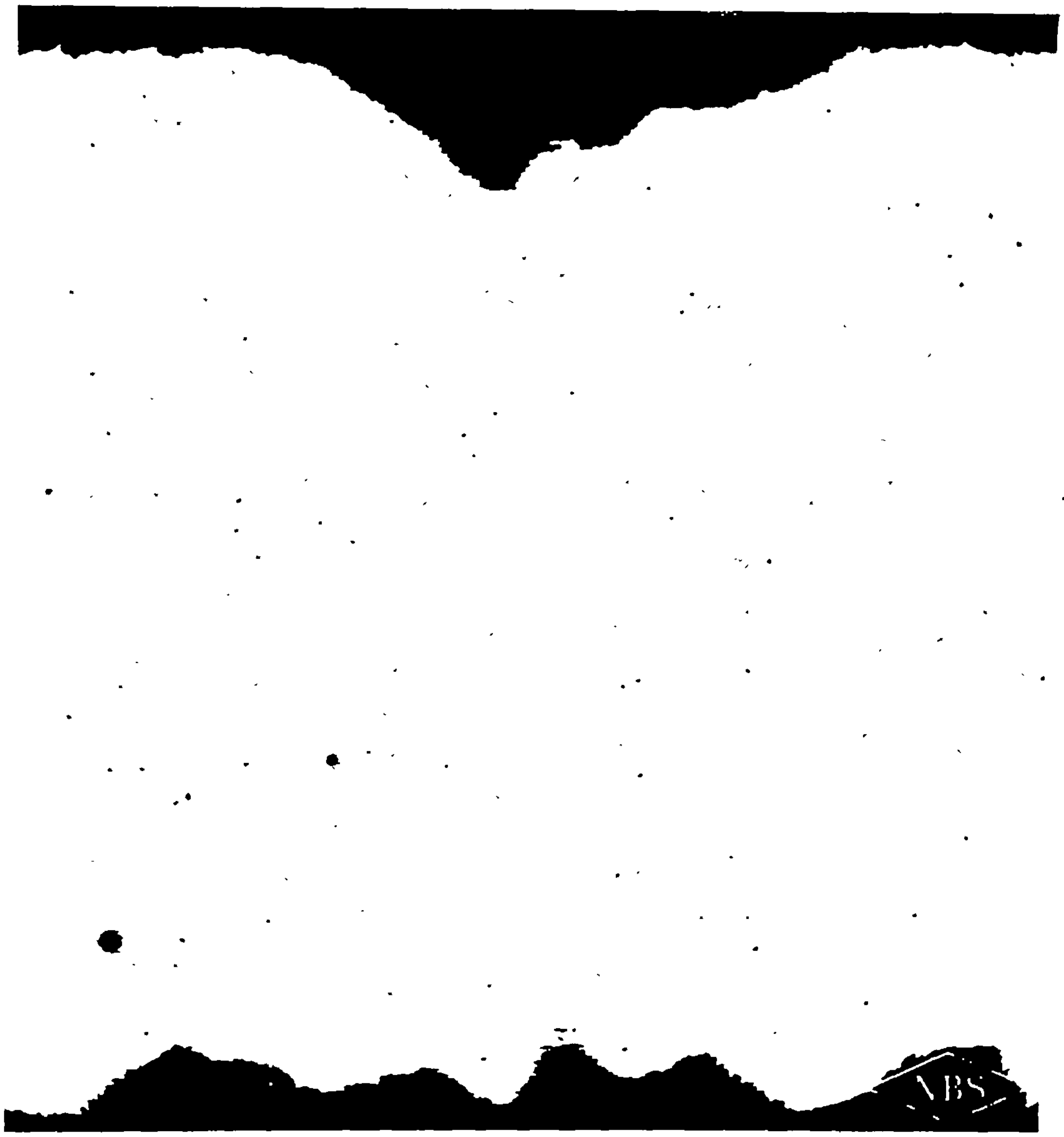

Figure 4.- Typical pits in ZK60A material after 18 months of exposure in marine atmosphere. Compare thickness of this sheet with that of one in figure 2. X100.

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